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UNITED STATES DEPARTMENT OF AGRICULTURE
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ANALYSIS OF VARIATIONS IN RICE YIELDS IN ARKANSAS, LOUISIANA, AND TEXAS 1/

This report summarizes an analysis of rice yields in Arkansas, Louisiana, and Texas for the purpose of indicating the probable cost of crop insurance on rice in these areas.

When the Federal Crop Insurance Act of 1938 provided for a wheat-crop insurance program it also provided for research to determine the feasibility of insurance for other crops. Insurance on cotton was first offered on the 1941 crop. In 1943 Congress appropriated funds only for the liquidation of the crop-insurance program. No insurance was written on crops for harvest in 1944 or on the winter-wheat crop for harvest in 1945. But in December 1944, Congress revived and expanded the program by an amendment to the Crop Insurance Act which authorized insurance on wheat, cotton, and flax as a permanent program beginning with the crops for harvest in 1945. The Corporation, therefore, offered insurance on the 1945 cotton, spring wheat, and flax crops, but not on the 1945 winter-wheat crop as that had already been planted.

Trial Insurance

The amendment also provided for trial insurance on corn and tobacco in 1945 and for the extension of the experimental program to not more than three additional crops in any one year thereafter. The Board of Directors of The Federal Crop Insurance Corporation has decided that more experience should be gained in insuring corn and tobacco before any other crops are insured experimentally. Therefore, no new crops are to be insured on a trial basis in 1946 or 1947. The trial insurance on a crop may be for not more than 3 years nor in more than 20 counties, and any extension to cover the country as a whole requires congressional action. The amendment specifies that insurance on a crop cannot be offered in a given county unless applications are filed covering at least 50 farms or one-third of the farms normally producing any of the crops authorized to be insured.

Insurance under the experimental program may be either (1) yield insurance for not more than 75 percent of the farm-average yield during a representative base period or (2) investment-cost insurance for not more than 75 percent of the investment in the crop, as determined by the Corporation.

1/ Prepared by Ralph R. Botts, Agricultural Economist.

Sample Records

As rather a large number of individual farm records covering rice production for a period of years were already on hand, it was thought that they should be examined to see how much variation occurs in yields of rice on individual farms from year to year, and about how much yield insurance might cost which would guarantee each farmer 75 percent of his own farm-average yield as under plan (1) above. 2/ Such a cost, as calculated here from the sample rice records, is a net or "pure" premium cost per acre per year, and is referred to later as the "average annual loss cost."

The sample includes records of yield for 1,272 rice farms, of which 31 percent were located in Arkansas, 56 percent in Louisiana, and 13 percent in Texas (table 1). About 59 percent of the records were for 7 years, 1934-40 inclusive, and 26 percent were for 6 years - in most cases the years 1935-40 inclusive. About 15 percent of the records were for either 4 or 5 years - usually consecutive years ending with 1940. All records for Texas were for 4, 5, or 6 years; none were available for as long as 7 consecutive years.

The number of growers and the number of annual yields, by years, are shown, by States, in table 2. Yields for 1,262 out of 1,272 farms were available for 1937, for example; apparently yield figures were not available that year for the other 10 farms. A total of 8,133 annual yields, occurring on 1,272 farms during the period 1934-40, are used in this study.

Table 1. - Number of growers, by States, grouped according to number of years of annual yields recorded

State	Number of years in history period				Total	
	7	6	5	4		
	Number growers	Number growers	Number growers	Number growers	Number growers	Percent
Arkansas	296	49	48	4	397	31
Louisiana	457	226	22	2	707	56
Texas	0	60	46	62	168	13
Total	753	335	116	68	1,272	XX
Percent	59	26	9	6	XX	100

Source: Records supplied by County AAA offices and canal companies.

2/ These records were obtained in 1940 and 1941 by BAE from County AAA offices and from canal companies. The number, systematically selected in each county, was usually in proportion to the rice production in such county in relation to State production.

Table 2. - Number of growers and number of annual yields included in sample, by States and by years

State	Growers	Number of annual yields, by years							
		1934	1935	1936	1937	1938	1939	1940	Total
	No.	No.	No.	No.	No.	No.	No.	No.	No.
Arkansas	397	317	346	393	394	394	392	386	2,622
Louisiana	707	464	690	703	706	706	705	699	4,673
Texas	168	0	110	120	162	161	145	140	838
Total	1,272	781	1,146	1,216	1,262	1,261	1,242	1,225	8,133

Source: Records supplied by County AAA offices and canal companies.

It appears that average yields for the sample farms in all three States were a little higher than State averages derived from data submitted by crop reporters (table 3). In Louisiana, for example, the annual average yields for sample farms were larger than the official estimates in all 7 years.

Table 3. - Official average yields per planted acre and average yields for sample farms, by years and by States

Year	Arkansas		Louisiana		Texas	
	BAE estimate	Sample	BAE estimate	Sample	BAE estimate	Sample
	Bushels	Bushels	Bushels	Bushels	Bushels	Bushels
1934	47.2	52.2	40.4	44.8	49.8	52.8
1935	44.0	51.2	42.0	47.4	52.0	51.4
1936	54.7	55.8	44.0	47.0	52.0	52.6
1937	56.0	55.8	40.0	46.2	50.0	54.8
1938	51.4	52.7	42.0	46.5	51.0	60.1
1939	50.0	50.4	44.0	47.3	56.4	57.5
1940	50.2	47.9	38.3	42.6		

Source: BAE estimates based on data supplied by crop reporters; "sample" average yields based on records supplied by County AAA offices and by canal companies.

Distribution of Yield Data

In the present study, an average yield was calculated for each farm for each year by dividing the total farm production by the planted acres. A simple average was taken of these annual yields to obtain a farm-average yield for the years covered by the records. 3/

Table 4. - Calculation of "annual yields as percentages of average yield" and "average annual loss cost" for one sample farm

Year	Annual yield	Percentage of average yield	Assumed "coverage" (75% of av. yield)	Annual loss cost (4) - (2)
(1)	(2)	(3)	(4)	(5)
	Bushels	Percent	Bushels	Bushels
1934	64.5	103.4	46.8	0
1935	65.0	104.2	46.8	0
1936	65.4	104.8	46.8	0
1937	64.9	104.0	46.8	0
1938	64.8	103.8	46.8	0
1939	71.6	114.7	46.8	0
1940	40.8	65.4	46.8	6.0
Total	437.0	XX	XX	6.0
Average	62.4	XX	XX	.86
75% of average	46.8	XX	XX	XX

Average loss cost as percentage of coverage = $\frac{.86}{46.8}$ = .018 = 1.8 percent

The annual yield for a farm each year was divided by that farm's average yield for the period to arrive at the ratios that the annual yields were of the farm-average yield. This was done for all farms, and the percentages are tabulated in table 5.

Note: The calculations for one farm are shown in table 4. Five annual yields were between 95 and 104.9 percent of the farm-average yield (col. 3). They were tabulated in the "95-104" group and are included among the 2,303 appearing

3/ Hereafter the average annual yield per acre for a farm in a particular year is referred to as its "annual yield," whereas "average yield" or "farm-average yield" refers to a simple average of the annual yields for that farm. In some instances, and particularly in Louisiana and Texas, yield data were by producers rather than by farms, as a producer often rents land from a canal compan and plants different acreages in different years.

in the next-to-last column of table 5. The annual yield in 1939 was 114.7 percent of the 62.4 bushel average for this farm, so one of the 1,584 annual yields tabulated for the "105-114" group was for this farm. Likewise, one of the 536 annual yields (the one in 1940) counted in the less-than-75 percent-of-average-yield-interval was for this farm.

It will be observed that the numbers in the last two columns of table 5 increase in size until the "95-104" group is reached; then they diminish. As this middle group includes all annual yields that were "about average" - and annual yields for a farm do tend to be like their average over a period of years - obviously more annual yields were tabulated in this middle group than in any other. Groups farther away from this middle group included fewer annual yields than those closer to it. For such a normal distribution the observed frequencies can be generalized and compared with theoretical frequencies that might be expected if additional yield data were obtained. 4/ Such a comparison indicated that somewhat more yields were reported at near their respective averages - tending to build up the number in the middle group - than would normally occur; and conversely, that additional records might show more annual yields that were lower or higher with respect to their averages than this sample indicates.

Table 5. - Distribution of number of annual yields grouped by the percentages that such annual yields were of their respective farm-average yields for the history years, by States 1/

Annual yield as percent of individual farm-average yield for history period	Arkansas	Louisiana	Texas	Total	
Percent	Number	Number	Number	Number	Percent
Less than 75	231	259	46	536	6.6
75-84	280	409	115	804	9.9
85-94	466	983	157	1,606	19.7
95-104	678	1,418	207	2,303	28.3
105-114	491	928	165	1,584	19.5
115-124	260	394	95	749	9.2
125-134	126	157	31	314	3.9
135 and over	90	125	22	237	2.9
Total	2,622	4,673	838	8,133	100.0

1/ Based on records for 397 farms in Arkansas, 707 in Louisiana, and 168 in Texas
Source: Records supplied by County AAA offices and canal companies.

4/ Standard deviation 17.6 percent.

Table 6. - Total number of annual yields, number involving losses, and average annual loss cost per farm per acre, by States

State	Total annual yields	Annual yields resulting in losses 1/		Average annual loss cost per farm acre 2/
	Number	Number	Percent	Bushels
Arkansas	2,622	231	8.8	.48
Louisiana	4,673	259	5.5	.32
Texas	838	46	5.5	.27
Total or average	8,133	536	6.6	.37

1/ A loss is assumed to have occurred when an annual yield is less than 75 percen of the farm-average yield.
2/ Sum of all losses in all years on all farms divided by the total number of annual yields, including both those involving losses and those that did not.
Source: Records supplied by County AAA offices and canal companies.

Estimated Cost of Insurance

The preceding discussion of the distribution of sample annual yields in relation to their respective farm averages would indicate that an estimate of insurance costs based on the variations in these yields might tend to be low. Whereas 536 of the yield figures, or 6.6 percent of the 8,133 annual yields, were below 75 percent of their respective farm agerages, the theoretical frequency was about 633 or 7.8 percent. On the average, we might expect slightly more than 1 percent of the yields to result in losses than the sample indicates

If the assumption were made that each farmer was insured for 75 percent of his own average yield during the years for which we have records, then losses might be said to have occurred each time an annual yield was less than that figure. For the farm illustrated in table 4, the losses in all years totaled 6.0 bushels, with a 7-year average loss of 0.86 bushel per acre per year. This figure of 0.86 bushel will be referred to as the "average annual loss cost per acre" and, if the yields during the history years are repeated (in any order) in the years of insurance, it is the premium in bushels that an insuring agency would have to charge this farmer each year in order to assure him a yield per acre equal to 75 percent of his average yield, and break even. It is, therefore, a "net" cost which covers losses only; it has not been "loaded" for administrative expenses.

Calculations similar to this (and to those in table 4) show that 812, or 64 percent, of the 1,272 farmers would have had no losses during their record period (table 7). An average annual loss of from 0.1 to 0.9 bushel per acre would have been experienced by 291, or 23 percent, of the farmers.

Note: The farm for which calculations are illustrated in table 4 (with an average annual loss cost of 0.86 bushel) is, therefore, included among these 291 farms.

Table 7. - Number of farms in specified "average annual loss-cost" classes, grouped by intervals of insured production 1/

Insured production (75 percent of farm-average yield)	Number of farms in designated "average annual loss-cost" intervals 2/								
	Zero losses	.1-.9 bu.	1.0-1.9 bu.	2.0-2.9 bu.	3.0 3.9 bu.	4.0 4.9 bu.	5.0 bu. and over	Total	
Bushels	No. growers	Number of growers						No. growers	Percent
10-19	17	4	3	0	0	0	0	24	2
20-29	104	35	15	4	1	6	0	165	13
30-39	440	172	55	17	8	1	2	695	55
40-49	208	69	29	11	5	0	0	322	25
50-59	40	10	5	3	1	1	0	60	5
60-69	3	1	1	0	0	0	1	6	3/
Total	812	291	108	35	15	8	3	1,272	XX
Percent	64	23	8	3	1	1	3/	XX	100

1/ Calculations are on a per-acre basis.
2/ The average-annual-loss-cost for a farm is a simple average of the annual losse per acre per year for that farm.
3/ Less than one-half of 1 percent.
Source: Records supplied by County AAA offices and canal companies.

As indicated in table 7, 87 percent of the farmers either had no losses or had losses that averaged less than 1 bushel per acre per year. The other 13 percent had losses averaging 1 bushel or more. Table 6 indicates that a premium of 0.37 bushel per acre collected from all farmers every year would have paid all losses that occurred in all years on all the sample farms.

The average annual-loss cost for the farm illustrated in table 4 was 1.8 percent of the assumed coverage (which is 75 percent of the farm-average yield). Therefore this farm was included among the 111 in the "1.0-1.9" percentage interval in table 8. Similar percentages were calculated for all farms and are tabulated in table 8. The average annual-loss cost was 10 percent or more of coverage for only 1.4 percent of the farms; and 5 percent or more of coverage for only 6 percent of the farms.

Table 8. - Distribution of farms according to specified "average-annual-loss-cost-as-percentage-of-coverage" groups, based on 1,272 farms in Arkansas, Louisiana, and Texas, 1934-40

Loss-cost as percent of coverage 1/	Arkansas	Louisiana	Texas	Total	
Percent	Number	Number	Number	Number	Percent
Zero	205	480	125	810	63.7
.1 - .9	52	62	11	125	9.8
1.0 - 1.9	50	54	7	111	8.7
2.0 - 2.9	34	35	7	76	6.0
3.0 - 3.9	13	23	5	41	3.2
4.0 - 4.9	12	18	4	34	2.7
5.0 - 5.9	12	7	5	24	1.9
6.0 - 6.9	7	3	0	10	.8
7.0 - 7.9	3	5	2	10	.8
8.0 - 8.9	3	6	1	10	.8
9.0 - 9.9	2	2	0	4	.3
10.0 and over	4	12	1	17	1.4
Total	397	707	168	1,272	100.1

1/ The assumed "coverage" is 75 percent of the average yield for the individual farm during the history period.

Summary and Conclusions

The data presented thus far indicate rather clearly that yields do not vary greatly on rice farms and that a net premium rate for insurance which guarantees the farmer 75 percent of his average yield would usually be rather low. If all farmers in the sample had been so insured in all years, a net premium of 0.37 bushel per acre collected from all farmers would have covered all losses. The annual yields are relatively stable, however, and only infrequently drop below 75 percent of the farm-average - with losses small in amount - so most farmers might not be conscious of a yield hazard and might not take 75 percent insurance even if offered, on rice. Insurance for more than 75 percent of the average yield would require a higher premium, of course, for obviously an annual yield is less likely to drop below 75 percent of the farm-average than 80 or 85 percent of that same average.

With a coverage for the individual farm equaling 80 or 85 percent of average yield, administrative expenses of handling more small claims would be greater. Furthermore, a coverage of 80 or 85 percent of average yield, if collected in full at the market price, might offer producers an opportunity for profit at the expense of the insurance - something that is avoided in all forms of insurance protection. It is avoided under "progressive coverage" in the case of all crops now insured in the crop-insurance program. Under this provision the coverage is increased as the crop progresses and additional expenses are incurred, so that a claim paid in connection with an early loss is less than a claim that would be paid to the same farmer later on. Safeguards to prevent

over-insurance would have to be rigidly applied in connection with a crop that is insured for 80 or 85 percent of average yield in the years when yields were generally low.

The last column of table 8 is repeated in table 9 in condensed form, so that the loss-cost-as-percent-of-75 percent-coverage may be compared with similar data for some sample peanut, cotton, and wheat farms, and for citrus groves. Comparing the two extremes, 64 percent of the rice farms had a "zero" loss cost as percentage of coverage, indicating that in no year did the annual yields for these farms drop below 75 percent of their respective farm averages whereas only 1 percent of the citrus groves had no losses. None of the rice farms had an average annual-loss cost as high as 15 percent of the assumed coverage (75 percent of the average yield for the individual farm), whereas 25 percent of the citrus groves had loss-cost percentages that high or higher. The next least hazardous crop appears to be peanuts. 5/ The "average-annual loss-cost-as-percent-of-coverage" might also be called a net "premium percentage" or the net premium rate as a percentage of the insurance offered.

Table 9. - Percentage distribution of farms (or groves) in designated "loss-cost-as-percent-of-coverage" groups, for selected crops

Loss cost as percentage of coverage 1/	Rice	Peanuts in the Southeast 2/	Five cotton counties 3/	Five wheat counties 4/	Citrus fruit 5/
Percent	Percent	Percent	Percent	Percent	Percent
Zero	64	33	16	29	1
.1 - 2.9	24	24	19	17	12
3.0 - 4.9	6	19	18	7	14
5.0 - 9.9	5	17	29	8	27
10.0 -14.9	1	7	12	5	21
15.0 and over	0	0	6	34	25
Total	100	100	100	100	100

1/ The "loss-cost" for a farm is the average annual loss (in bushels per acre) that would have occurred if a yield each year were insured which was 75 percent of the farm-average yield during base-period years. The assumed "coverage" is, as stated, 75 percent of the individual farm-average yield for the history years.
2/ Based on 51 sample farms in North Carolina and 76 in Georgia for the period 1936-41, inclusive.
3/ Based on 125 sample farms, approximately 25 of which were located in each of the following counties: Washington and Chicasaw, Miss., and Colbert, Lauderdale, and Marengo, Ala.
4/ Based on 375 sample farms, 75 of which were located in each of the following counties: Golden Valley, No. Dak.; Sandusky, Ohio; Morton, Kans.; Whitman, Wash. and York, Penn.
5/ Based on 203 citrus groves in California, Florida, and Texas.

5/ For a detailed discussion see "An Analysis of the Variations in Peanut Yields in North Carolina and Georgia," by Ralph R. Botts, Peanut Journal and Nut World, December 1942.

Table 10. - Analysis of variance in rice yields for 276 farms with 7 years of annual yields, located in 5 counties in Arkansas, 1934-40

Source of variation	Degrees of freedom	Sum of squares	Mean square
Total	1,931	299,580.98	
Years	6	12,506.13	2,084.36
All farms	275	125,532.99	
Counties	4	31,736.03	7,934.01
Farms within counties	271	93,796.96	346.11
All farms x years	1,650	161,541.86	97.90
Year x county	24	3,258.30	135.76
Year x farms within counties	1,626	158,283.56	97.35

Pooled discrepance	97.9	70%
Component for years	7.2	5%
Component for farms (within counties)	35.5	25%
Total	140.6	100%

A more detailed and complex analysis was made of the source of the variation in yields which occurred on 276 of the farms in 5 counties in Arkansas which had 7 years of yield records. The results of these calculations are shown in table 10. In short, it was found that county-average yields were significantly different; but the reaction of yields to years was much the same in all counties, regardless of whether the level of the county-average yield was high or low. As shown at the bottom of table 10, the variance in yields among individual farmers in individual years averaged about as follows: 5 percent due to the year in which the yield occurred, 25 percent due to differences between farms, and 70 percent due to other factors, aside from farm and year variation, over which there was no statistical control. If, in an insurance program, an individual coverage were offered each farmer based on his own average yield, the variation in yields due to the "farm" component (25 percent) of course would not affect the risk.

Individual farm yields over a long period are needed if they are to reflect the full extent of losses to which an insuring agency might be subjected under individual yield-insurance contracts. The question might well be raised, therefore, as to whether yields of rice in the particular years for which these records were obtained (1934-40) were representative of the variations in yields that might occur over a longer period. If there happened to be little variation in annual yields during these years, we might expect any estimate of insurance costs based on such yields to be low, as the hazards of production over the longer period would not be fully reflected by the data. The reverse would be true, of course, if the yields varied more during the 7 years than the average for a longer and more representative period.

The official BAE State-average yields of rice for Arkansas for 32 years, 1909-40, were examined to throw some light on this question. The annual State-average yields for the period 1934-40 averaged to 50.5 bushels, whereas they

averaged to 47.6 bushels during the 32-year period. The average deviation of the annual figures from their 7-year average was 3.0 bushels, whereas the average deviation of the 32 annual figures from their 32-year average was 3.5 bushels.

In an effort to ascertain about how much a rate computed from the farm-yield data for the years 1934-40 would have to be adjusted to reflect the hazards over the longer period - exclusive of any loading for other factors such as adverse selectivity - a further analysis was made of the Arkansas recor This analysis was based entirely on the assumption that the relationship existing between annual State-average yields and annual State-average loss costs for the 7 years, 1934-40, would remain the same for the 32-year period, 1909-40

The simple average of the annual yields for sample farms (in Arkansas) in a particular year was plotted (as a percentage of the 7-year average yield for the same farms) against the average annual-loss cost for the sample farms in that year (also as a percentage of the same 7-year average yield). Thus there were 7 points, the coordinates of each point representing the combined sample-farm experience in 1 year, the relative size of yield being plotted as the abcissae of the point and the relative amount of loss locating the ordinate of the point or its height above the x-axis. A free-hand curve was then drawn through these 7 points to arrive at an average relationship between the two variables as it existed for sample farms during the 7 years for which individual farm data were available.

The State-average yield for each year during the period 1909-40 was then computed as a percentage of the 32-year average yield, and these 32 percentages were each read against the curve which had been fitted to the 7-year data in the manner described. Thus a loss percentage was obtained for each of 32 years The average percentage was computed and the result was multiplied by the 32-year average yield to obtain an average-loss cost per acre, per year, in bushel which might be expected to measure approximately the insurance risk over the longer period.

This analysis indicated that losses over the 32-year period would average about 0.64 bushel per acre in Arkansas, instead of the 0.48 bushel which was derived from the records for the last 7 of the 32 years (table 6). Therefore, according to this projection of the data, a pure premium cost calculated from the records would have to be loaded by about one-third to cover production hazards not reflected by the short-period records. A similar projection of the data was not made in connection with the Louisiana and Texas records.

Summarizing the study, it must be recognized that the variability of year-to-year yields in this crop, as indicated by the sample records, is remarkably low - largely because of control over the water supply. Rice yields may be reduced on individual farms in certain years by insects, by plant diseases, by windstorm, or by salt-water damage (in Louisiana and Texas), and locally by minor causes; but the data indicate that there were relatively few severe crop failures on the sample farms during the 7 years 1934-40.

Insects and diseases are present in most areas every year, reducing rice yields and affecting its quality. The principal insect enemies are the stink-bug and the stalk-borers; while the principal plant diseases are leaf-spot and stem rot. There are occasional hurricanes and other windstorms, and the time of their occurrence in relation to the maturity of the grain determines to a

great extent the degree of loss. Lodging is also caused by insects and diseases and is a varietal characteristic. Salt-water damage occurs in Louisiana and Texas when there has been little rainfall during the growing season. Frost damage has been found in the newer areas of northern Arkansas, though such losses are now being prevented somewhat by the planting of early-maturing varieties.

It may be pointed out that if the yields on a particular farm were reduced every year by the occurrence of one or more hazards, the reported yields might still be rather stable from year to year. One would not be able to determine from the record that actual yields had been below potential yields. But a study of yield variations does enable us to determine the extent to which annual yields have dropped below their average and thus estimate about what insurance would cost which covers all annual losses in yield below a given percentage of the farm-average yield. This determination was one of the purposes of this study.